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(54) **DISPLAY STACK**

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G06F 1/16 (2006.01)
B29D 11/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 1/1643*** (2013.01); ***B29D 11/00663*** (2013.01)

(58) **Field of Classification Search**
CPC G02F 1/13338; G06F 3/0412; G06F 1/1643; B29D 11/00663
USPC 349/12
See application file for complete search history.

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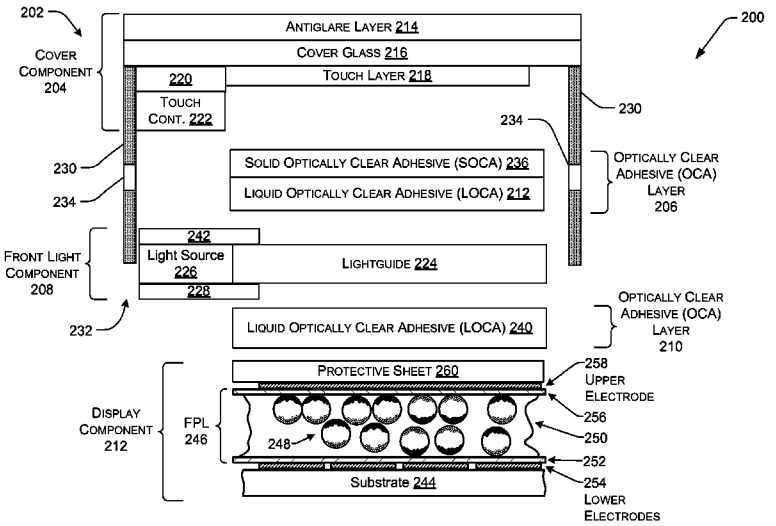
(57) **ABSTRACT**

Described herein are electronic devices that includes a display stack having a cover component atop a lightguide component and a display component below the lightguide component. In some instances, the cover component including an antiglare etching applied to a top surface of a coverglass and a touch pattern applied to a bottom surface of the coverglass. In some cases, an optically clear adhesive layer formed from two types of optically clear adhesive may be located between the cover component and the lightguide component and a ring adhesive may be applied to around an outer edge of the cover component, the optically clear adhesive and the lightguide component.

20 Claims, 5 Drawing Sheets



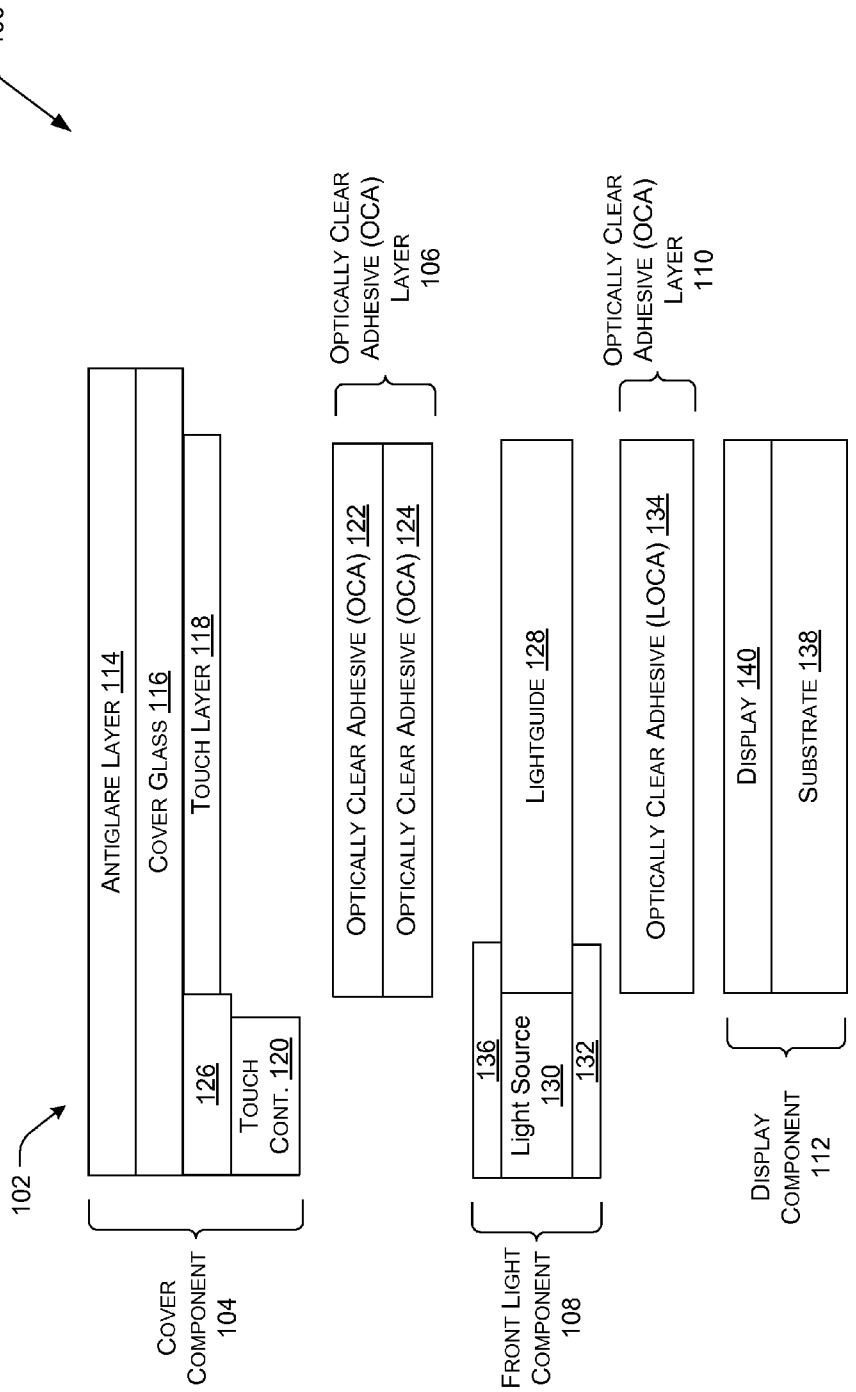

100
102
Antiglare Layer 114
Cover Glass 116
Touch Layer 118
126
Touch Cont. 120
Cover Component 104
Optically Clear Adhesive (OCA) 122
Optically Clear Adhesive (OCA) 124
Optically Clear Adhesive (OCA) Layer 106
136
Light Source 130
132
Lightguide 128
Front Light Component 108
Optically Clear Adhesive (LOCA) 134
Optically Clear Adhesive (OCA) Layer 110
Display 140
Substrate 138
Display Component 112

Fig. 1

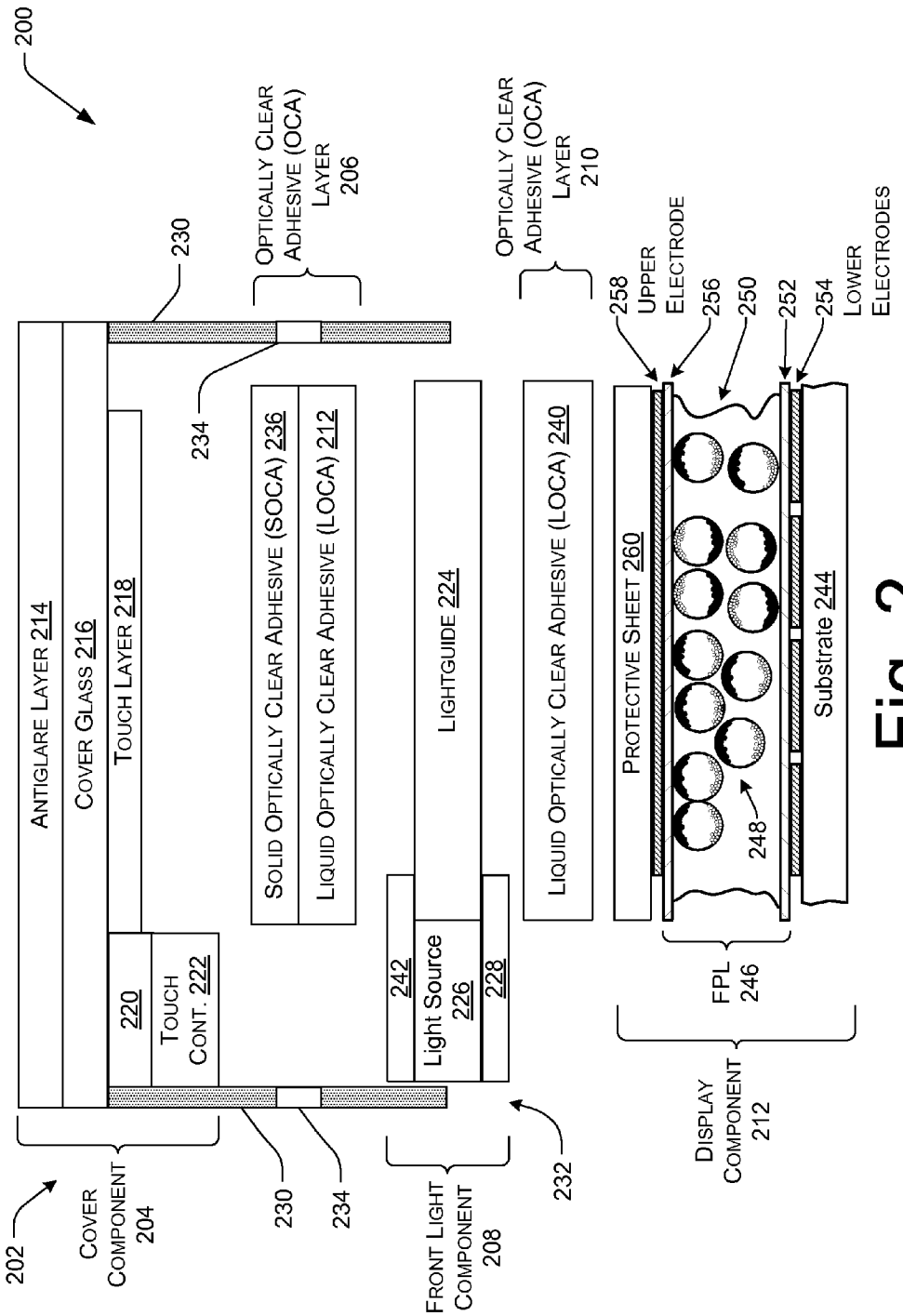

200
202
Cover Component 204
Antiglare Layer 214
Cover Glass 216
Touch Layer 218
220
Touch Cont. 222
230
234
Optically Clear Adhesive (OCA) Layer 206
Solid Optically Clear Adhesive (SOCA) 236
Liquid Optically Clear Adhesive (LOCA) 212
Front Light Component 208
242
Light Source 226
228
Lightguide 224
232
Optically Clear Adhesive (OCA) Layer 210
Liquid Optically Clear Adhesive (LOCA) 240
Display Component 212
Protective Sheet 260
258
Upper Electrode
256
250
FPL 246
248
252
254
Lower Electrodes
Substrate 244

Fig. 2

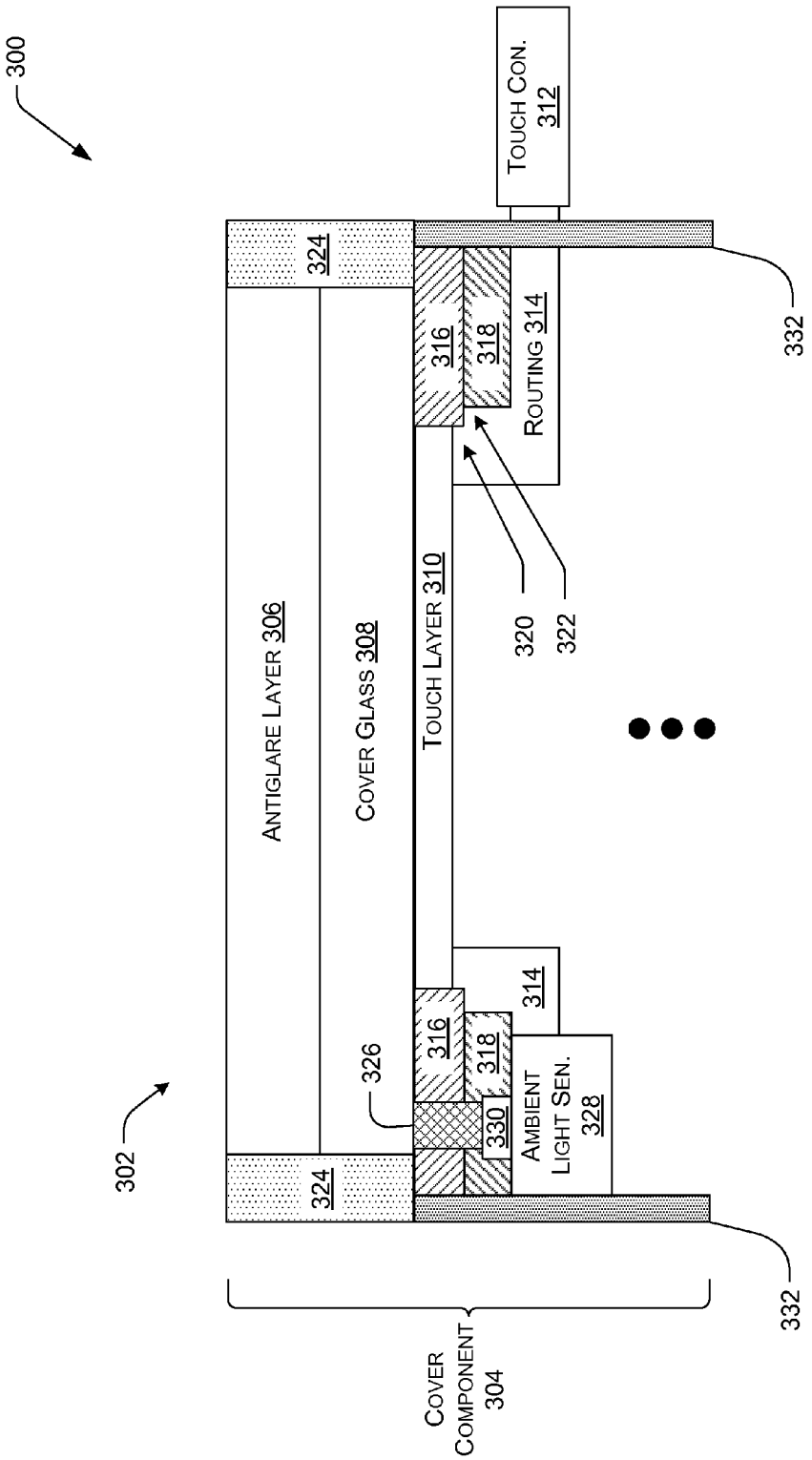

300
302
ANTIGLARE LAYER 306
COVER GLASS 308
TOUCH LAYER 310
TOUCH CON. 312
ROUTING 314
316
318
320
322
324
326
330
AMBIENT LIGHT SEN. 328
332
COVER COMPONENT 304

Fig. 3

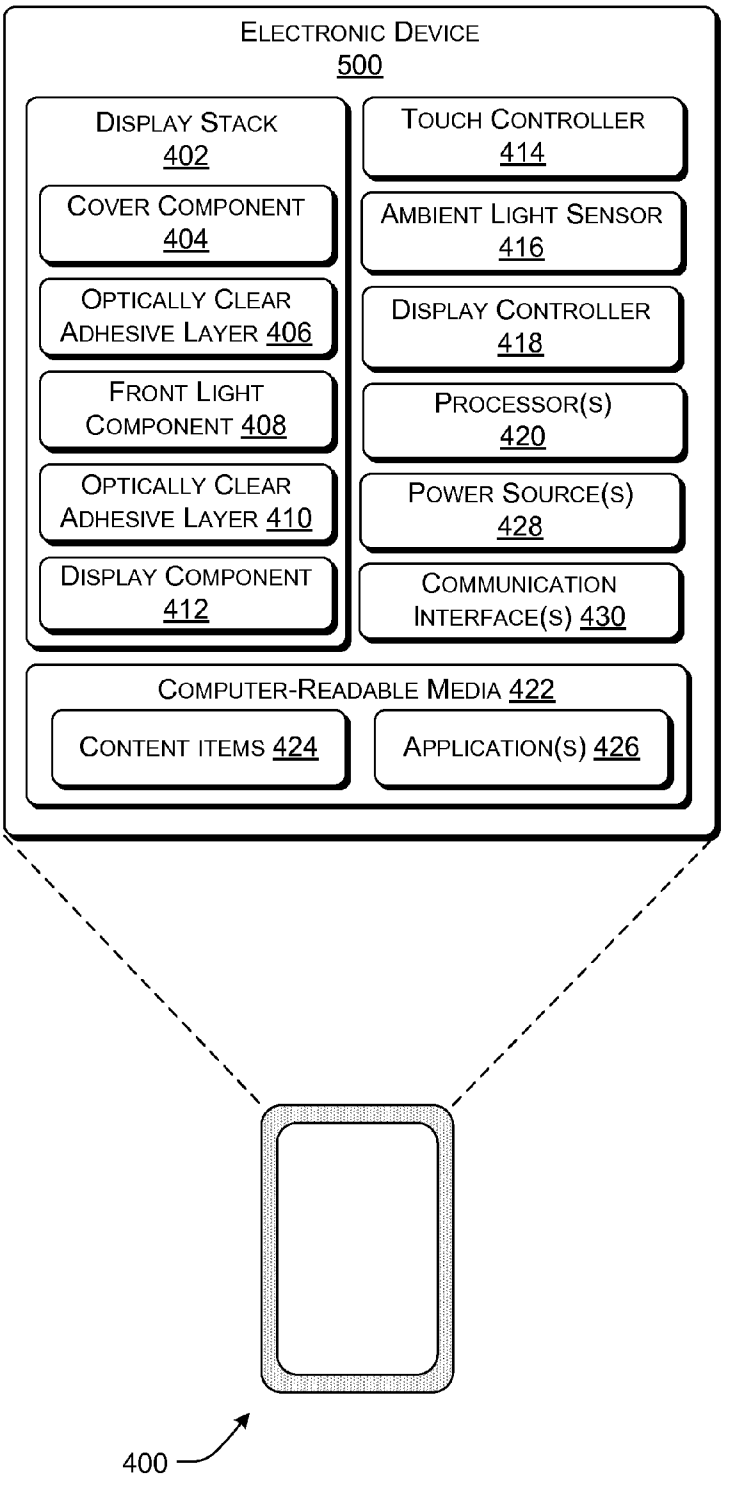

ELECTRONIC DEVICE
500
DISPLAY STACK
402
COVER COMPONENT
404
OPTICALLY CLEAR ADHESIVE LAYER 406
FRONT LIGHT COMPONENT 408
OPTICALLY CLEAR ADHESIVE LAYER 410
DISPLAY COMPONENT
412
TOUCH CONTROLLER
414
AMBIENT LIGHT SENSOR
416
DISPLAY CONTROLLER
418
PROCESSOR(S)
420
POWER SOURCE(S)
428
COMMUNICATION INTERFACE(S) 430
COMPUTER-READABLE MEDIA 422
CONTENT ITEMS 424
APPLICATION(S) 426
400

Fig. 4

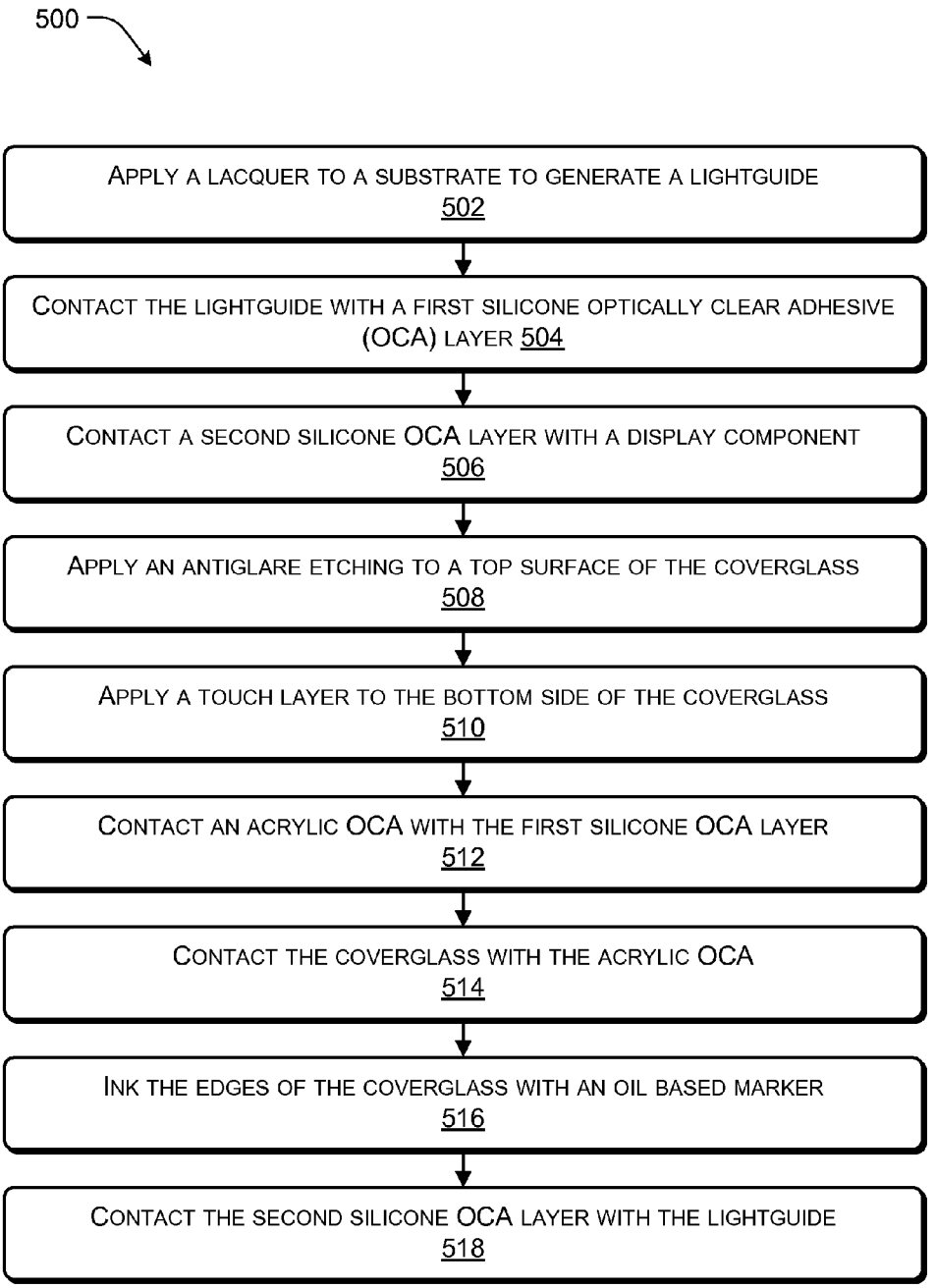

500
APPLY A LACQUER TO A SUBSTRATE TO GENERATE A LIGHTGUIDE
502
CONTACT THE LIGHTGUIDE WITH A FIRST SILICONE OPTICALLY CLEAR ADHESIVE (OCA) LAYER 504
CONTACT A SECOND SILICONE OCA LAYER WITH A DISPLAY COMPONENT
506
APPLY AN ANTIGLARE ETCHING TO A TOP SURFACE OF THE COVERGLASS
508
APPLY A TOUCH LAYER TO THE BOTTOM SIDE OF THE COVERGLASS
510
CONTACT AN ACRYLIC OCA WITH THE FIRST SILICONE OCA LAYER
512
CONTACT THE COVERGLASS WITH THE ACRYLIC OCA
514
INK THE EDGES OF THE COVERGLASS WITH AN OIL BASED MARKER
516
CONTACT THE SECOND SILICONE OCA LAYER WITH THE LIGHTGUIDE
518

Fig. 5

DISPLAY STACK

BACKGROUND

A large and growing population of users is enjoying entertainment through the consumption of digital content, such as music, movies, images, electronic books, and so on. The users employ various devices with electronic displays such as electronic book ("eBook") readers, cellular telephones, smart phones, portable media players, tablet computers, wearable computers, laptop computers, netbooks, desktop computers, televisions, appliances, home electronics, automotive electronics, augmented reality devices, and so forth to view the digital content. Electronic displays may present various types of information, such as user interfaces, device operational status, digital content items, and the like, depending on the kind and purpose of the associated device. The appearance and quality of a display can affect the user's experience with the electronic device and the content presented thereon. Accordingly, finding ways to enhance user experience and satisfaction continues to be a priority.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description is set forth with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical items or features.

FIG. **1** illustrates an example schematic cross-section of a display stack of an electronic device.

FIG. **2** illustrates another example schematic cross-section of a display stack of an electronic device.

FIG. **3** illustrates example partial schematic cross-section of a display stack of an electronic device.

FIG. **4** illustrates a functional block diagram of an electronic device that includes the display stack of FIGS. **1-3**.

FIG. **5** illustrates an example flow diagram showing an illustrative process for forming the display stack of FIGS. **1-3**.

DETAILED DESCRIPTION

This disclosure describes, in part, electronic devices that include electronic displays for rendering digital content to one or more users. In particular, this disclosure describes ways to provide a thinner, lighter, and/or cheaper electronic device. In general, a display stack has a number of layers, including a number of substrates and one or more adhesive layers to bond the substrates. For example, a display stack may include a display component that with a number of additional layers or components stacked on top. For instance, a front light component may be stacked atop the display component and a cover component may be stacked atop the front light component. In some instances, the various components of the display stack may be joined or adhered together using one or more layers of optically clear adhesive (OCA).

In one implementation, the cover component includes a coverglass having a top surface exposed to the user and a bottom surface. In some examples, the top surface of the coverglass has an antiglare layer formed from a coating or film. In one particular implementation, the top surface of the coverglass may be etched using a physical or a chemical process to impart antiglare properties to the coverglass. In some embodiments, use of etching to impart antiglare properties to the coverglass may eliminate the need for a bezel around the exterior surface of the display, as well as provide improved durability and resistance to damage (for example, in some instances antiglare films may peel or separate from the coverglass). In one example, the top surface of the coverglass may also have other properties, such as antireflective properties, anti-smudging or anti-fingerprinting properties, and/or anti-cracking properties.

In some implementations, the coverglass may have a touch layer or touch pattern applied to the bottom surface to form a display capable of receiving inputs, as well as displaying content. In some cases, the touch layer or touch pattern may be formed from traces of indium tin oxide (ITO), copper, printed ink or the like. For example, traces of ITO may be deposited or patterned onto the bottom surface of the coverglass, a conductive ink may be printed on the bottom surface of the coverglass, or a pre-formed metal mesh technology or wiring (e.g., silver nanowires or carbon nanotubes) may be adhered or laminated to the bottom surface of the coverglass.

In some examples, a touch sensing layer capable of detecting the proximity and location of an object placed adjacent to, substantially adjacent to, or touching the top surface of the display may be part of the display stack. In some particular implementations, a single layer multi-touch pattern may be utilized. By utilizing a single layer touch pattern in lieu of a multi-layer touch pattern, the touch pattern may be applied to a surface of the coverglass without the need for additional substrates.

In some implementations, the cover component includes a black mask arranged beneath at least a portion of the coverglass. For example, black ink or a black tape may be applied to selected portions or locations of the underside of the coverglass and arranged to prevent errant light from reflecting off various components the display stack. In some instances, the black mask may also be utilized to hide the various component of the display stack, such as the touch controller, touch flex, and/or a light source (e.g., one or more light-emitting diodes (LEDs)) from the view of a user. In some implementations, the black mask may have two layers formed by applying two layers of black ink, two layers of black tape, or one layer of black ink and one layer of black tape to the bottom surface of the coverglass. By utilizing a two layer black mask, the black mask provides improved light obstruction, as well as improved durability with regards to the touch sensor, as will be described in more detail below with respect to FIG. **3**.

In some examples, the front light component includes a light source and a lightguide. The lightguide may include a substrate formed from a transparent thermoplastic (such as PMMA), a layer of lacquer and multiple grating elements that function to propagate light from the light source towards the top surface of the display stack, thus illuminating the content presented on the display. For example, the lightguide may be formed by applying a layer of lacquer to the substrate to create the grating elements of the lightguide, the grating elements may be embossed to the layer of lacquer, and the lightguide may be ultra-violet (UV)-cured. In one particular implementation, the grating elements are formed by applying the lacquer to the substrate in a manner consistent to form a positive relief.

In some implementations, the light source may be connected to a flexible printed circuit (FPC) to control the amount and volume of light generated. The LEDs selected for inclusion in the light source may have a color that is optimized for the type of display being used. For instance, multiple different color temperature LEDs having particular

color ratios there between may be selected to ensure a proper color from the collection of LEDs when lighting the display. Furthermore, the color of the LEDs may be tuned over time to compensate for changes in the lightguide, as well based on other factors, such as the aging of the LEDs, the environment that the device is indented for, among others. In one particular implementation, the light source may include six LEDs utilized in combination.

In general, the lightguide is surrounded by two layers of OCA to prevent errant light from escaping the lightguide in an undesirable manner. The first OCA layer may be formed from two types of OCA: a first type of OCA having predetermined ultra-violet (UV) properties and the second type having predetermined refractive properties. In various implementations, the particular UV properties may be tailored or selected based on the type and characteristics of the component of the display stack and the refractive properties may be tailored or selected based on the type and characteristics of the front light component (e.g., the light source and/or the lightguide). For example, the first type of OCA may have a luminous transmittance of 90% or greater above 400 nanometer (nm) wavelengths, 5% or less below 300 nm wavelength, and between 5% and 90% between 300 and 400 nm wavelength. In one particular example, the luminous transmittance of the first type of OCA may be zero percent below 380 nm wavelength and greater than 90% above 400 nm wavelength. In another example, the refractive index for the second OCA may be in a range from about 1.3 to about 1.51. In another example, the refractive index of the second OCA may be in the range of about 1.39 to 1.45. In one particular example, the refractive index of the second OCA may be about 1.41.

In some implementations, the first type of the OCA may be an acrylic OCA having a UV cut and the second type of OCA may be a silicone OCA having specific refractive indexes. In one particular example, the OCA layer is formed by contacting an acrylic OCA film to a silicone OCA film and UV-curing or hardening. In another particular example, the OCA layer is formed by applying a liquid OCA (LOCA) to the underside of an OCA film or a solid OCA (SOCA). By substituting a LOCA for one of the OCA films, the number of defects and steps associated with the manufacturing process of the display stack may be reduced, resulting in a cheaper higher quality display. For example, when a LOCA is utilized, the first OCA layer may no longer need to undergo the auto glazing process to shrink or remove air gaps within the OCA layer, as the LOCA is better able to fill the air gaps between the two types of OCA.

The second OCA layer may be formed from primarily from silicone OCA having the predetermined refractive index. In some examples, the second layer of OCA may be a formed by die-cutting a SOCA film to match the length and width of the lightguide and UV-curing or hardening around the corners and/or the portion of the perimeter. Thereafter, the remaining OCA may be UV-cured. In other examples, a liquid silicone OCA may be placed near a center of the display stack and pressed outwards towards a perimeter of the display stack while UV curing.

In some implementations, the display component may include a reflective display, such as an electronic paper display, a reflective liquid crystal display (LCD), or the like. Electronic paper displays represent an array of display technologies that can mimic the look of ordinary ink on paper. In contrast to backlit displays, electronic paper displays typically reflect light, much as ordinary paper does. In addition, electronic paper displays can be bi-stable, meaning that these displays are capable of holding text or other rendered images even when very little or no power is supplied to the display. Some examples of the display component that can be used with the implementations described herein include bi-stable LCDs, micro electromechanical system (MEMS) displays, such as interferometric modulator displays, cholesteric displays, electrophoretic displays, electrofluidic pixel displays, electrowetting displays, photonic ink displays, gyricon displays, and the like. In other implementations, or for other types of electronic devices, the display component may include an active display such as a LCD, a plasma display, a LED display, an organic light emitting diode (OLED) display, and so forth. Accordingly, implementations herein are not limited to any particular display technology.

In an illustrative implementation, the display stack **102** may be formed by combining a number of substrates and/or components one atop the other. For instance, FIGS. **1-3**, described below, illustrate example schematic cross-section of the display stack **102**.

FIG. **1** illustrates a first example of a schematic cross-section **100** of a display stack of an electronic device **100**. The cross-section **100** illustrates a display stack **102** including individual layers of a cover component **104**, OCA layer **106**, front light component **108**, OCA layer **110**, and display component **112**. In the illustrated example, the cover component **104** includes an antiglare layer **114** applied to a top surface of a coverglass **116** and a touch layer **118** applied to a bottom surface of the coverglass **116**. In some cases, the touch layer **118** may also be electronically coupled to touch controller **120**, for example, directly or via a flexible circuit (not shown) to from a touch sensor or touch enabled display capable of both presenting content and receiving user inputs related to the presented content.

In general, the coverglass **116** may be configured to protect the display from damage, such as scratching, chipping, peeling, as well as to provide rigidity and stiffness to the overall device **100** (e.g., to prevent the electronic device **100** from bending or deforming when held). Thus, the coverglass **116** may be configured to run the entire width and depth of the electronic device **100**. In some cases, the coverglass **116** may have a hardness rating that is resistant to a 9H pencil or greater, while in other cases, the coverglass **116** may have a hardness rating between 3H pencil and 9H pencil. In general, the coverglass **116** may be manufactured to be less than 1 millimeter (mm) thick and, in some implementations, may be in the range of 0.5 mm to 0.7 mm. In some examples, the coverglass **116** may be formed from a substantially optically clear glass. In other examples, the coverglass **116** may be formed from a substantially optically clear plastic.

The antiglare layer **114** may be formed by applying an antiglare coating or film to a top surface of the coverglass **116**. For example, the top surface of the coverglass **116** may be coated or dipped in the antiglare coating which may be cooled or UV-cured. In other examples, an antiglare film may be adhered to the top surface of the coverglass **116**, for instance, using an OCA, LOCA, or SOCA. In other implementations, the outer antiglare layer **114** may be selectively etched into the top surface of the coverglass **116**. In one example, the antiglare etching may be formed by applying a chemical spray or bath to the top surface of the coverglass **116**. In some cases, the antiglare layer **114** may be formed to include additional proprieties such as antireflective properties, anti-smudging or anti-fingerprinting properties, and/or anti-cracking properties.

In general, a touch sensor includes a touch pattern (e.g., rows and columns in a grid or diamond shape) and a touch

controller **120**. However, unlike traditional touch sensors that typically include a touch component located directly atop the display component **112**, the touch sensor described herein, may include a touch layer **118** applied to the coverglass **116** that forms part of the cover component **104**. In some particular implementations, the touch layer **118** may be a single layer multi-touch pattern that may be traced upon a single side of a substrate, such as the coverglass **116**.

The touch layer **118** may include traces made from ITO, printed ink, metal mesh technologies, or the like applied to a bottom surface of the coverglass **116**. For example, traces of ITO may be deposited or patterned (e.g., to form a diamond or grid) onto the bottom surface of the coverglass **116** using physical vapor deposition, electron beam evaporation, or sputter deposition techniques among others. In other examples, a conductive ink may be printed on the bottom surface of the coverglass **116** or a pre-formed metal mesh technology or wiring (e.g., silver nanowires or carbon nanotubes) may be adhered or laminated to the bottom surface of the coverglass **116** to form the touch layer **118**. Furthermore, in some instances the touch layer **118** may include a transparent conductor other than, or in addition to those described above.

In some implementations, to protect the touch layer **118** additional dielectric materials may be incorporated into the antiglare layer **114** or the coverglass **116** above the touch layer **118**. For example, an acrylic material may reside atop the coverglass **116** for protection, with this a color of this acrylic layer being tuned to ensure that a resulting color of the display stack **102** viewed by a user is correct. The antiglare layer **114** may provide additional protection for the touch layer **118**, for example, in the form an antiglare etching, coating, or film and having antiglare proprieties, antireflective properties, anti-smudging or anti-fingerprinting properties, and/or anti-cracking properties. Furthermore, the touch layer **118** may be filled or surrounded by an OCA (such as, OCA **122** or **124** of OCA layer **106**) when joined with the front light component **108**, which substantially eliminates the opportunity for air gaps or partial bubbles to form around or near the material used to from the touch layer **118** improving the overall efficacy and accuracy of the resulting touch sensor.

In some implementations, the cover component **104** includes at least one black mask **126** arranged beneath at least a portion of the coverglass **116**. For example, black ink or a black tape may be applied to selected portions or locations of the underside of the coverglass **116** and arranged to prevent errant light from traveling through the coverglass **116** at the selected locations. In some particular examples, a pattern or image may be cut from the black mask **126** such that light may escape to the surface of the display, for example, to illuminate one or more control images or areas located in the boarder of the display to a user.

The front light component **108** generally includes a lightguide **128** connected to a light source **130**. The lightguide **128** may include a substrate (not shown) formed from a transparent thermoplastic (such as PMMA), a layer of lacquer and multiple grating elements that function to propagate light from the light source **130** towards the top surface of the display stack **102**, thus illuminating the content presented on the display. For example, the lightguide **128** may be formed by applying a layer of lacquer to the substrate to create the grating elements of the lightguide **128**, the grating elements may be embossed to the layer of lacquer to from a positive or negative relief and the lightguide **128** may be UV-cured. Alternatively, the substrate of the lightguide **128** and the grating elements may be manufactured as a single element, such as via an injection molding process. In some instances, the UV lacquer is made of a cross-linked, tri-functional polymer material that co-polymerizes to a plastic solid when exposed to a high-intensity UV light source.

In some implementations, the light source **130** may be connected to a flexible printed circuit (FPC) **132** to control the amount and volume of light generated. In some instances, the light source **130** (e.g., one or more LEDs) may connected to the FPC **132** via one of the OCA layers **106** or **110**. For example, the FPC **132** may be connected to the light source **130** via a strip of SOCA or the like. The FPC **132** may also be connected to the lightguide **128** via the OCA layers **106** and **110**. In some instances, the FPC **132** may include a light-diffusing reflective coating (e.g., in the form of a white matte finish), which may help to diffuse and reflect light from the light source **130** and, hence, increase the uniformity of the light across the front of the display screen.

The layers of OCA **106** and **110** above and below the lightguide **216** help maintain the light generated by the light source **130** within the lightguide **128**, as well as to join the cover component **104** and the display component **112** with the front light component **108**. In general, the OCA layers **106** is arranged atop the front light component **108** and the OCA layer **110** is arranged beneath the front light component **108**.

As illustrated, the OCA layer **106** may be formed from two types or layers of OCA, OCA **122** and OCA **124**. The OCA **122** may have predetermined UV properties and the OCA **124** (for example, a luminous transmittance percentage of zero below 350 nm wavelength and above 90% over and 400 nm wavelength) may have predetermined refractive index (for example, in the range of 1.39 to 1.45). In various implementations, the particular UV properties may be tailored or selected based on the type and characteristics of the component of the display stack and the refractive properties may be tailored or selected based on the type and characteristics of the front light component **108** (e.g., the light source **130** and/or the lightguide **128**). In some implementations, the OCA **122** may be an acrylic OCA having a UV cut and the OCA **124** may be a silicone OCA having specific refractive indexes. In one particular example, the OCA layer **106** may be formed by contacting an acrylic OCA film **122** to a silicone OCA film **124** and UV-curing or hardening. By utilizing both an acrylic OCA and a silicone OCA to form the OCA layer **106**, the OCA layer **106** may be configured to have a desired UV cut and refractive index.

The OCA layer **110** may be formed from a single layer of silicone LOCA **134** having the predetermined refractive index. As one example, the LOCA **134** may comprise Loctite® 5192™, an optically transparent UV-curable silicone-based adhesive available from Henkel AG & Co. KGaA of Disseldorf, Germany. In some instances, the LOCA **134** may include a photoinitiator to facilitate UV curing. Examples of photoinitiators include cationic photoinitiators such as organic iodonium or sulfonium salts. The LOCA **134** may be applied to a surface such a by rolling using a wet coating method or other suitable technique, followed by UV curing (e.g., using a fusion lamp).

In addition, to the OCA layers **106** and **110**, a white tape **136** or other type of light-diffusing reflective coating may be laid along a perimeter of the lightguide **128**, which again may help to diffuse light from the light source **130** and increase the uniformity of the light from the light source **130**. Although shown as being attached to the perimeter of the OCA layer **106**, the white tape **136** or other type of

light-diffusing reflective coating may be further laid along other elements of the display stack **102**, such as the light-guide **128**.

In the illustrated example, the front light component **108** resides atop the display component **112**, which includes a substrate **138** and a display **140**. The display **140** may be may a reflective display, such as bi-stable LCDs, micro MEMS displays, such as interferometric modulator displays, cholesteric displays, electrophoretic displays, electrofluidic pixel displays, electrowetting displays, photonic ink displays, gyricon displays, and the like. In other implementations, or for other types of electronic devices, the display component may include an active display such as a LCD, a plasma display, a LED display, and/or OLED display, and so forth. Accordingly, implementations herein are not limited to any particular display technology.

In some instances, the display **140** may include a FPL that includes e-ink capsules, as well as the fluid in which the capsules move up or down in as described above with reference to electronic-paper displays. In some examples, the display **140** may include a plastic film structure onto which the e-ink is coated using a roll-to-roll process. Thereafter, a conductive transparent electrode plastic film may be combined with an adhesive layer and a release sheet to form one implementation of the FPL. As another example, the FPL may include a plurality of pixel elements (not shown), each containing liquid subject to electrowetting activation. For example, voltage may be applied to individual pixel elements to modify the surface tension of the liquid and thereby change the appearance of the pixel element.

FIG. **2** illustrates a second example schematic cross-section **200** of a display stack of an electronic device **200**. The cross-section **200** illustrates the display stack **202** including individual layers of a cover component **3244**, OCA layer **206**, front light component **208**, OCA layer **210**, and display component **212**. In the illustrated example, the cover component **204** includes an antiglare layer **214** applied to a top surface of a coverglass **216** and a touch layer **218** applied to a bottom surface of the coverglass **216**. In some cases, the touch layer **218** may also be electronically coupled to touch controller **222**, for example, directly or via a flexible circuit (not shown) to from a touch sensor or touch enabled display capable of both presenting content and receiving user inputs related to the presented content.

In general, the coverglass **216** may be configured to protect the display from damage, such as scratching, chipping, peeling, as well as to provide rigidity and stiffness to the overall device **200** (e.g., to prevent the electronic device **100** from bending or deforming when held). Thus, the coverglass **216** may be configured to run the entire width and depth of the electronic device **100**. In some cases, the coverglass **216** may have a hardness rating that is resistant to a 9H pencil or greater, while in other cases, the coverglass **216** may have a hardness rating between 3H pencil and 9H pencil. In general, the coverglass **216** may be manufactured to be less than 1 mm thick and, in some implementations, may be in the range of 0.5 mm to 0.7 mm. In some examples, the coverglass **216** may be formed from a substantially optically clear glass. In other examples, the coverglass **216** may be formed from a substantially optically clear plastic.

The antiglare layer **216** may be formed by applying an antiglare coating or film to a top surface of the coverglass **216**. For example, the top surface of the coverglass **216** may be coated or dipped in the antiglare coating which may be cooled or UV-cured. In other examples, an antiglare film may be adhered to the top surface of the coverglass **216**, for instance, using an OCA, LOCA, or SOCA. In other implementations, the outer antiglare layer **214** may be selectively etched into the top surface of the coverglass **216**. In one example, the antiglare etching may be formed by applying a chemical spray or bath to the top surface of the coverglass **216**. In some cases, the antiglare layer **216** may be formed to include additional proprieties such as antireflective properties, anti-smudging or anti-fingerprinting properties, and/or anti-cracking properties.

In general, a touch sensor includes a touch pattern (e.g., rows and columns in a grid or diamond shape) and a touch controller **222**. In some particular implementations, the touch layer **218** may be a single layer multi-touch pattern that may be traced upon a single side of a substrate, such as the coverglass **216**. The touch layer **218** may include traces made from ITO, printed ink, metal mesh technologies, or the like applied to a bottom surface of the coverglass **216**. For example, traces of ITO may be deposited or patterned onto the bottom surface of the coverglass **216** using physical vapor deposition, electron beam evaporation, or sputter deposition techniques, among others. In other examples, a conductive ink may be printed on the bottom surface of the coverglass **216** or a pre-formed metal mesh technology or wiring may be adhered or laminated to the bottom surface of the coverglass **216** to form the touch layer **218**. Furthermore, in some instances the touch layer **218** may include a transparent conductor other than, or in addition to those described above.

In some implementations, the cover component **204** includes at least one black mask **220** arranged beneath at least a portion of the coverglass **216**. For example, black ink, paint, or a black tape may be applied to selected portions or locations of the underside of the coverglass **216** and arranged to prevent errant light from reflecting or shining off of components located along the side of the display stack **202** (e.g., the touch controller **222**). In some particular examples, a pattern or image may be cut from the black mask **3260** such that light may escape to the surface of the display, for example, to illuminate one or more control images or areas located in the boarder of the display to a user.

The front light component **208** generally includes a light-guide **224** connected to a light source **226**. The lightguide **224** may include a substrate (not shown) formed from a transparent thermoplastic (such as PMMA), a layer of lacquer and multiple grating elements that function to propagate light from the light source **226** towards the top surface of the display stack **202**, thus illuminating the content presented on the display. For example, the lightguide **224** may be formed by applying a layer of lacquer to the substrate to create the grating elements of the lightguide **224**, the grating elements may be embossed to the layer of lacquer to from a positive or negative relief and the lightguide **224** may be UV-cured. Alternatively, the substrate of the light-guide **224** and the grating elements may be manufactured as a single element, such as via an injection molding process. In some instances, the UV lacquer is made of a cross-linked, tri-functional polymer material that co-polymerizes to a plastic solid when exposed to a high-intensity UV light source.

In some implementations, the light source **226** may be connected to a FPC **228** to control the amount and volume of light generated. In some instances, the light source **226** (e.g., one or more LEDs) may connected to the FPC **228** via one of the OCA layers **206** or **210**. For example, the FPC **228** may be connected to the light source **226** via a solid strip of SOCA or the like. The FPC **228** may also be connected to the lightguide **224** via the OCA layers **206** and **210**. In some

instances, the FPC **228** may include a light-diffusing reflective coating (e.g., in the form of a white matte finish), which may help to diffuse and reflect light from the light source **226** and, hence, increase the uniformity of the light across the front of the display screen.

In some implementations, a ring adhesive **230** may be applied around the outer edge of the display stack **202**. The ring adhesive **230** may be utilized to bond and hold the various components of the display stack **202** together in a coherent manner. In some cases, such as the illustrated example, the ring adhesive **230** may extend partially down in the z direction, for instance, to substantially encase or encompass the cover component **204** and the front light component **208**. In some implementations, the ring adhesive **230** is configured to prevent light from escaping or leaking out of the display stack **202**. In some specific examples, the display may be configured to be flexible such that a user may deform or deflect the entire electronic device **100** to some degree, for instance, to receive a user input. To do so the ring adhesive **230** may be bonded on the perimeter of the display stack **202** and an air gap, generally indicated by **232**, may be located underneath the main portion of the display stack **202**.

In some specific examples, the ring adhesive **230** may have one or more compliant or flexible areas, such as areas **234**. For example, the ring adhesive **230** may be formed from very high bond (VHB) material (one example of which is available from 3M®), while the areas **234** may be formed from a soft or flexible material, such as various foams, foam tapes, liquids, and/or an air gap. By providing the flexible areas **234**, a display stack **202** may be generated that allows various portions of the electronic device **200** to flex at desired locations, for example, to receive user inputs.

In the illustrated example, the two layers of OCA **206** and **210** are arranged above and below the lightguide **224** help maintain the light generated by the light source **226** within the lightguide **224**, as well as to join the cover component **204** and the display component **212** with the front light component **208**. In general, the OCA layers **206** is arranged atop the front light component **208** and the OCA layer **210** is arranged beneath the front light component **208**.

As illustrated, the OCA layer **206** may be formed from two types or layers of OCA, OCA **236** and OCA **238**. The OCA **236** may have predetermined UV properties and the OCA **238** may have predetermined refractive index. In various implementations, the particular UV properties may be tailored or selected based on the type and characteristics of the component of the display stack and the refractive properties may be tailored or selected based on the type and characteristics of the front light component **208** (e.g., the light source **226** and/or the lightguide **224**). For example, the OCA **236** may have a luminous transmittance of 90% or greater above 400 nanometer (nm) wavelengths, 5% or less below 300 nm wavelength, and between 5% and 90% between 300 and 400 nm wavelength. In one particular example, the luminous transmittance of the OCA **236** may be zero below 380 nm wavelength and greater than 90% above 400 nm wavelength. In another example, the refractive index for the OCA **238** may be in a range from about 1.3 about 1.51. In another example, the refractive index of the OCA **238** may be in the range of about 1.39 to 1.45. In one particular example, the refractive index of the OCA **238** may be about 1.41. In illustrated example, the OCA layer **206** may be formed by applying a LOCA **238** to the underside of an OCA film **236**. For example, a silicone LOCA may be applied to an acrylic OCA film under a pressure of 50 Pascal (Pa) or less for 20 to 30 seconds using a vacuum lamination process. By substituting a LOCA for one of the OCA films in this manner, the number of bubbles (e.g., practical bubbles) that typically form when OCA films are bonded to each other may be reduced and/or eliminated, in some cases, improving overall optical quality of the display. By reducing the number of bubbles that form between the OCA films the number of mechanical failures that may occur during stress testing when the bubbles in the display stack **202** are exposed to heat, pressure, or a combination thereof may be reduced improving overall manufacturing yields, thus reducing overall costs.

The OCA layer **210** may be formed from a single layer of silicone LOCA **240** having the predetermined refractive index. As one example, the LOCA **240** may comprise Loctite® 5192™, an optically transparent UV-curable silicone-based adhesive available from Henkel AG & Co. KGaA of Disseldorf, Germany. In some instances, the LOCA **240** may include a photoinitiator to facilitate UV curing. Examples of photoinitiators include cationic photoinitiators such as organic iodonium or sulfonium salts. The LOCA **240** may be applied to a surface such a by rolling using a wet coating method or other suitable technique, followed by UV curing (e.g., using a fusion lamp).

In addition, to the OCA layers **206** and **210**, a white tape **242** or other type of light-diffusing reflective coating may be laid along a perimeter of the lightguide **224**, which again may help to diffuse light from the light source **226** and increase the uniformity of the light from the light source **226**. Although shown as being attached to the perimeter of the OCA layer **206**, the white tape **242** or other type of light-diffusing reflective coating may be further laid along other elements of the display stack **202**, such as the lightguide **224**.

In the illustrated example, the front light component **208** resides atop the display component **212**. As illustrated, the component **212** is a reflective display that includes the substrate **244**, such as of glass or other suitable material, and a FPL **246**, which serves as the image-displaying component. In this example, the FPL **246** includes capsules, generally indicated by **248**, as well as a fluid, generally indicated by **250**, in which the capsules **248** are suspended. In addition, the FPL **246** includes a lower plastic film **330052** onto which the fluid **250** and capsules **248** are deposited, such as using a roll-to-roll process. A grid or pattern of lower electrodes **254** is associated with the lower plastic film **252**. Similarly, an upper transparent plastic film **256** may be located on the upper side of the fluid **250** for containing the fluid **250** and the capsules **248**.

The display component, also includes at least one upper electrode **258** associated with the upper film **256**. In some examples, the upper electrode **256** may include a grid or pattern of transparent electrodes formed from ITO or other suitable transparent conductive material. As one particular example, aligned pairs of the upper and lower electrodes **256** and **254** may each form a single pixel of the display stack **202**. For instance, each capsule **248** may include dark and light particles inside the capsule **248**. A positive charge on an electrode pair may cause a first color of particle to rise toward the upper plastic film **256** while a negative charge on an electrode pair may cause a second color of particle to rise toward the plastic film **256**. A display controller (not shown) may control the charge applied to each electrode pair. Furthermore, in some examples, the pixels (i.e., electrode pairs) may be controlled by applying a sequence of voltages to each pixel, instead of just a single value as in a typical LCD. These sequences of voltages may be referred to as

"waveforms," and may be employed to prevent over-charging of the capsules **248**, prevent damage to the capsules **248**, and so forth.

A protective sheet **260** may be assembled atop the FPL **246**, so that the FPL **246** is sandwiched between the protective sheet **260** and the substrate **244**. Thus, the protective sheet **260**, the FPL **246**, and the substrate **244** may be assembled or laminated together to form the display component **104**. In some implementations of, described herein, the protective sheet **260** may be manufactured at a reduced thickness by removing various treatments such as the UV treatments, typically associated therewith, as the coverglass **216** of the display stack **202** includes an UV etching as described above.

FIG. **3** illustrates example partial schematic cross-section **300** of the **302** electronic device of FIG. **4**. The cross-section **300** illustrates select elements of the cover component **304** of the display stack **302**. In the illustrated example, the cover component **304** includes an antiglare layer **306** applied to a top surface of a coverglass **308** and a touch layer **310** applied to a bottom surface of the coverglass **308**. In some cases, the touch layer **310** may also be electronically connected to touch controller **312**, for example, directly or via a routing **314** (e.g., an ITO routing or flexible circuit) to from a touch sensor or touch enabled display capable of both presenting content and receiving user inputs related to the presented content.

In general, a touch sensor includes a touch pattern (e.g., rows and columns in a grid or diamond shape) and a touch controller **312**. In some particular implementations, the touch layer **310** may be a single layer multi-touch pattern that may be traced upon a single side of a substrate, such as the coverglass **308**. The touch layer **310** may include traces made from ITO, printed ink, metal mesh technologies, or the like applied to a bottom surface of the coverglass **308**. For example, traces of ITO may be deposited or patterned (e.g., to form a diamond or grid) onto the bottom surface of the coverglass **308** using physical vapor deposition, electron beam evaporation, or sputter deposition techniques among others. In other examples, a conductive ink may be printed on the bottom surface of the coverglass **308** or a pre-formed metal mesh technology or wiring (e.g., silver nanowires or carbon nanotubes) may be adhered or laminated to the bottom surface of the coverglass **308** to form the touch layer **310**. Furthermore, in some instances the touch layer **310** may include a transparent conductor other than, or in addition to those described above.

In the illustrated example, the cover component **304** includes two black masks **316** or **318** arranged beneath at least a portion of the coverglass **308**. The black masks **316** and **318** may be a tape, paint, ink or the like applied to the bottom surface of the coverglass **308** to capture or block light from leaking out of the display stack **302**. As illustrated, each black mask **316** and **318** has a thickness greater than that of the touch layer **310** resulting in the steps **320** and **322** forming between the touch layer **310** and the touch controller **312**. Thus, the routing **314** may be utilized to connect the touch layer **310** to the touch controller **312**, as the touch layer **310** may not be flexible enough to travel over the step **320** and/or **322** without cracking.

In the illustrated example, the black mask includes a two layer mask formed from the black mask **316** being arranged atop the black mask **318**. In the illustrated example, the black mask **316** is shown as extending past the edge of the black mask **318** to create a two step or tiered black mask. By utilizing two black masks **316** and **318** with two steps **320** and **322**, the flexible circuit **314** that couples the touch controller **312** to the touch layer **310** is able to traverse two smaller steps **320** and **322** in lieu of one larger step reducing the risk that the routing **314** will break or crack under stress.

The coverglass **308** may be configured to protect the display from damage, such as scratching, chipping, peeling, as well as to provide rigidity and stiffness to the overall device **300** (e.g., to prevent the electronic device **100** from bending or deforming when held). Thus, the coverglass **308** may be configured to run the entire width and depth of the electronic device **300**. In some cases, the coverglass **308** may have a hardness rating that is resistant to a 9H pencil or greater, while in other cases, the coverglass **308** may have a hardness rating between 3H pencil and 9H pencil. In general, the coverglass **308** may be manufactured to be less than 1 millimeter (mm) tall and, in some implementations, may be in the range of 0.5 mm to 0.7 mm. In some examples, the coverglass **308** may be formed from a substantially optically clear glass. In other examples, the coverglass **308** may be formed from a substantially optically clear plastic.

The antiglare layer **308** may be formed by applying an antiglare coating or film to a top surface of the coverglass **308**. For example, the top surface of the coverglass **308** may be coated or dipped in the antiglare coating which may be cooled or UV-cured. In other examples, an antiglare film may be adhered to the top surface of the coverglass **308**, for instance, using an OCA, LOCA, or SOCA. In other implementations, the outer antiglare layer **306304** may be selectively etched into the top surface of the coverglass **308**. In one example, the antiglare etching may be formed by applying a chemical spray or bath to the top surface of the coverglass **216**. In some cases, the antiglare layer **308** may be formed to include additional proprieties such as antireflective properties, anti-smudging or anti-fingerprinting properties, and/or anti-cracking properties.

In the illustrated example, the antiglare layer **306** and the coverglass **308** have an edge ink **324** applied to sustainably around the entire edge of the cover component **304** (e.g., the side walls and bottom chamfer of the coverglass **308**). The edge inking **324** may be an oil based marker or ink that is applied to the edge of the coverglass **308** and cured at a temperature of 50° C. to prevent light from traveling through the coverglass **308** as if the coverglass **308** were a lightguide and shining off various components (e.g., the touch controller **312**) of the display stack **302** arranged along the edge of the coverglass **308**. In some cases, the oil based maker may be applied by a robot programmed to walk the perimeter of the coverglass **308**. In other cases, the oil based marker or ink maybe applied by using a dispensing pen. In some specific examples, the edge ink **324** may be applied using techniques such as Pad Printing, ink-jet, spray, among others.

In some implementations, the amount of light emitted by the front light component may be variable. For instance, upon opening a cover (not shown) of the electronic device **300**, the light from the front light may gradually increase to its full illumination over a period of time. In other instances, the amount of light emitted by the front light component may depend on the amount of light present in the environment surrounding the electronic device **300**. Thus in the illustrated example, the cover component **304** includes a window **326** to allow light to travel through the antiglare layer **306**, the coverglass **308**, and the black masks **316** and **318** to access an ambient light sensor **328**. In this example, the illumination of the front light component may be based at least in part on the amount of ambient light detected by the ambient light sensor **328**. For instance, the front light may emit a greater concentration of light if the ambient light

sensor **328** detects relatively little ambient light in the environment, and may emit a lesser concentration of light if the ambient light sensor **328** detects a relatively large amount of ambient light in the environment. In some implementations, the ambient light sensor **328** may be configured to maintain a contrast ratio for the display stack **302** that is within a predetermined range. In some specific implementations, an ink layer **330** may be located over the ambient light sensor **328** to color match the ambient light sensor **328** with the coverglass **308**, for instance, to prevent the user from visually perceiving the ambient light sensor **328** when viewing the display stack **302**.

In the illustrated example, a ring adhesive **332** may be applied around the outer edge of the cover component **304**. The ring adhesive **332** may be utilized to bond and hold the various components of the display stack **302** together. In some cases, such as the illustrated example, the ring adhesive **332** may extend partially down in the z direction, for instance, to substantially encase or encompass the cover component **304**. In some implementations, similar to the edge ink **324**, the ring adhesive **332** may be configured to prevent light from escaping or leaking out of the display stack **302**. In some specific examples, the display may be configured to be flexible such that a user may deform or deflect the entire electronic device **100** to some degree, for instance, to receive a user input. To do so the ring adhesive **332** may be bonded on the perimeter of the cover component **304** and an air gap may be located underneath the main portion of the cover component **304** to allow for flexing of the display stack **302**.

FIG. **4** illustrates an example electronic device **400** that includes a display stack **402402**. In general, the device **400** may comprise any type of mobile electronic device (e.g., an electronic book reader, a tablet computing device, a laptop computer, a multifunction communication device, a portable digital assistant (PDA), etc.) or non-mobile electronic device (e.g., a desktop computer, a television, etc.). In addition, while FIG. **4** illustrates several example components of the electronic device **400**, it should be appreciated that the device **400** may also include other conventional components, such as an operating system, system busses, input/output components, and the like.

In general, the display stack includes a cover component **404**, a first OCA layer **406**, a front light component **408**, a second OCA layer **410**, and a display component **412**. In one implementation, the cover component **404** includes a coverglass having an outer antiglare layer exposed to a user of the electronic device. In one implementation, the outer antiglare layer is formed by applying an antiglare coating or film to the top surface of the coverglass. In other implementations, the outer antiglare layer may be selectively etched onto the top surface of the coverglass. In one example, the antiglare etching may be formed by applying a chemical spray or bath to the top surface of the coverglass. In some cases, the antiglare etching may be formed to include additional proprieties such as antireflective properties, anti-smudging or anti-fingerprinting properties, and/or anti-cracking properties. In some instances, the outer antiglare layer may be manufactured such that the resulting surface includes a hardness rating that is greater than a predefined threshold. In this way, the cover component **404** may have an outer surface that is resistant to scratches caused by objects having a hardness rating less than the predefined threshold (e.g., at least a hardness rating that is resistant to a 3H pencil).

In some implementations, the coverglass may have a touch layer or touch pattern applied to the bottom surface to form a display capable of receiving inputs, as well as displaying content. In some cases, the touch layer or touch pattern may be formed from traces of indium tin oxide (ITO). For example, traces of ITO may be deposited or patterned onto the bottom surface of the coverglass, for example, using physical vapor deposition, electron beam evaporation, or sputter deposition techniques, among others. In other cases, a conductive ink may be printed on the bottom surface of the coverglass or a pre-formed metal mesh technology or wiring (e.g., silver nanowires or carbon nanotubes) may be adhered or laminated to the bottom surface of the coverglass to form the touch layer.

In general, a touch controller **414** may be utilized in combination with the touch layer to form a touch-sensitive display stack **402**. Thus, the display stack **402** may be capable of both accepting user touch input and rendering content in response to or corresponding to the touch input. As several examples, the touch layer and the touch controller **414** may together form a capacitive touch sensor incorporated into the display stack **402**, a force sensitive resistance (FSR) sensor, an interpolating force sensitive resistance (IFSR) sensor, or any other type of touch sensor. In this manner, the display stack **402** may provide a touch-sensitive display capable of detecting user inputs, as well as displaying content. In some instances, the touch sensor may be capable of determining an amount of pressure or force associated with a touch input. In some specific examples, the touch layer may be electronically coupled with the touch controller **414** via a flexible circuit (not shown).

In some implementations, the cover component also includes a black mask arranged beneath at least a portion of the coverglass. For example, black ink or a black tape may be applied to selected portions or locations of the underside of the coverglass and arranged to prevent errant from reflecting or shinning off various component of the display stack **402**. In some instances, the black mask may also be utilized to hide various components of the display stack, such as the touch controller **414** and the flexible circuit. In some implementations, the black mask may be a two layer black mask. For example, the two layer black mask may be formed by applying two layers of black ink, two layers of black tape, or one layer of black ink and one layer of black tape to the bottom surface of the coverglass. In the two layer design, the black mask may be arranged to provide a stepped or tiered effect, such that the flexible circuit climbs or traverses two smaller steps in lieu of one larger step when coupling the touch controller **414** to the touch layer. By utilizing the two step design, display stack **402** becomes more resilient, as the likelihood of damage to the flexible circuit is reduced.

In some specific implementations, in addition to the black mask, the outer edges of the coverglass may be inked with an oil based marker or ink to prevent light from traveling through the coverglass, as if the coverglass was a lightguide and, thus, to prevent the light from leaking through the coverglass at undesirable locations and/or shining off various components of the display stack **402** arranged along the edge of the coverglass. In general, the edge inking improves the overall quality of the display, particularly in dark environments.

The electronic device **400** may also include a front light component **408** (which may alternatively be a backlight component in the case of a backlit display) for lighting the display stack **402**. The front light component **408** may include a lightguide portion and a light source. The lightguide portion may include a substrate including a transparent thermoplastic polymer. For example, the lightguide

portion can include an acrylic polymer. In one implementation, the lightguide portion can include polymethylmethacrylate (PMMA). In a particular implementation, the lightguide portion can include a substrate, a layer of lacquer and multiple grating elements formed in the layer of lacquer. The multiple grating elements may be configured to propagate light to illuminate the display component **412**. In some specific examples, the multiple grating elements may be formed using a positive relief technique when applying the layer of lacquer to the substrate.

In some implementations, the light source may be connected to a flexible printed circuit (FPC) to control the amount and volume of light generated. The LEDs selected for inclusion in the light source may have a color that is optimized for the type of display being used. For instance, multiple different color temperature LEDs having particular color ratios there between may be selected to ensure a proper color from the collection of LEDs when lighting the display. Furthermore, the color of the LEDs may be tuned over time to compensate for changes in the lightguide, as well based on other factors, such as the aging of the LEDs, the intended environment. In one particular implementation, the light source may include six LEDs utilized in combination.

Furthermore, the amount of light emitted by the front light component **408** may vary. For instance, upon a user opening a cover of the electronic device **400**, the light from the front light component **408** may gradually increase to its full illumination. In some instances, the electronic device **400** includes an ambient light sensor **416** and the amount of illumination of the front light component **408** may be based at least in part on the amount of ambient light detected by the ambient light sensor **416**. For example, the front light component **408** may be dimmer if the ambient light sensor **416** detects relatively little ambient light, such as in a dark room; may be brighter if the ambient light sensor **416** detects ambient light within a particular range; and may be dimmer or turned off if the ambient light sensor **416** detects a relatively large amount of ambient light, such as direct sunlight.

In addition, the settings of the display component **412** may vary depending on whether the front light component **408** is on or off or based on the amount of light provided by the front light component **408**. For instance, the electronic device **400** may implement a larger default font or a greater contrast when the front light component **408** is off compared to when the front light component **408** is on. In some instances, the electronic device **400** maintains, when the front light component **408** is on, a contrast ratio for the display component **412** that is within a certain defined percentage of the contrast ratio when the front light component **408** is off.

In general, the OCA layers **406** is arranged atop the front light component **408** and the OCA layer **410** is arranged beneath the front light component **408**. The OCA layers **406** and **410** may be arranged around the lightguide to prevent errant light from escaping the lightguide in an undesirable manner. The OCA layer **406** may be formed from two types or layers of OCA: the first type having predetermined UV or luminous transmittance rating and the second type having a predetermined refractive index. In various implementations, the particular UV properties may be tailored or selected based on the type and characteristics of the component of the display stack and the refractive properties may be tailored or selected based on the type and characteristics of the front light component (e.g., the light source and/or the lightguide).

In some implementations, the first type of the OCA may be an acrylic OCA having a UV cut and the second type of OCA may be a silicone OCA having specific refractive indexes. In one particular example, the OCA layer **106** is formed by contacting an acrylic OCA film to a silicone OCA film and UV-curing or hardening. In another example, the OCA layer **406** may be formed by applying a liquid OCA (LOCA) to the underside of an OCA film or a SOCA. For example, a silicone LOCA is applied to an acrylic OCA film under a pressure of 50 Pascal (Pa) or less for 20 to 30 seconds using a vacuum lamination process. By substituting a LOCA for one of the OCA films in this manner, the number of bubbles or particle bubbles that typically form between the OCA films may be reduced and/or eliminated, in some cases, improving overall optical quality of the display and reducing mechanical failures that may occur when the bubbles in the display stack **402** are exposed to heat, pressure, or a combination thereof.

The OCA layer **406** may be formed from a single layer of silicone OCA having the predetermined refractive index. In some examples, the OCA layer **406** may be a formed by die-cutting a SOCA film to match the length and width of the lightguide and UV-curing or hardening around the corners and/or the portion of the perimeter. Thereafter, the remaining OCA may be UV-cured. In other examples, a liquid silicone OCA may be placed near a center of the display stack and pressed outwards towards a perimeter of the display stack while UV curing.

The display stack **402** also includes a display component **412** and a corresponding display controller **418**. For instance, the display stack **402** may include a display component **412** that may present content via one or more image producing technologies. In various examples, the display component **412** may include a reflective display, such as an electronic paper display, a reflective LCD, or the like. Electronic paper displays represent an array of display technologies that can mimic the look of ordinary ink on paper. In addition, electronic paper displays can be bi-stable, meaning that these displays are capable of holding text or other rendered images even when very little or no power is supplied to the display. Some examples of the display component **412** that may be used with the implementations described herein include bi-stable LCDs, MEMS displays, such as interferometric modulator displays, cholesteric displays, electrophoretic displays, electrofluidic pixel displays, electrowetting displays, photonic ink displays, gyricon displays, and the like. In other implementations, or for other types of electronic devices **400**, the display component **412** may include an active display such as a LCD, a plasma display, a LED display, an organic light emitting diode (OLED) display, and so forth. Accordingly, implementations herein are not limited to any particular display technology.

In one implementation, the display component **412** comprises an electrophoretic display that moves particles between different positions to achieve different color shades. For instance, in a pixel that is free from a color filter, the pixel may be configured to produce white when the particles within this pixel are located at the front (i.e., viewing) side of the display. When situated in this manner, the particles reflect incident light, thus giving the appearance of a white pixel. Conversely, when the particles are pushed near the rear of the display, the particles absorb the incident light and, hence, cause the pixel to appear black to a viewing user. In addition, the particle may situate at varying locations between the front and rear sides of the display to produce varying shades of gray. Furthermore, as used herein, a "white" pixel may comprise any shade of white or off white, while a "black" pixel may similarly comprise any shade of black.

In another implementation, the display component **412** comprises an electrophoretic display that includes oppositely charged light and dark particles. In order to create white, the display controller **418** may move light particles to the front side of the display component **412** by creating a corresponding charge at an electrode near the front of the display component **412** and moves the dark particles to the back of the display component **412** by creating a corresponding charge at an electrode near the back. In order to create black, meanwhile, the display controller **418** changes the polarities and moves the dark particles to the front of the display component **412** and the light particles to the back of the display component **412**. Furthermore, to create varying shades of gray, the display controller **418** may utilize different arrays of both light and dark particles. In some cases, the particles may be contained in individual transparent capsules. In a particular example, the capsules can have a diameter included in a range of 35 micrometers to 45 micrometers. The capsules can be suspended in a fluid, such as a liquid polymer, between a transparent upper electrode grid layer and a lower electrode grid layer separated by a gap of approximately 50 micrometers to 200 micrometers.

In still another implementation, the display component **412** may include an electrowetting display that employs an applied voltage to change the surface tension of a liquid in relation to a surface. For instance, by applying a voltage to a hydrophobic surface, the wetting properties of the surface may be modified so that the surface becomes increasingly hydrophilic. As one example of an electrowetting display, the modification of the surface tension acts as an optical switch by contracting a colored oil film when a voltage is applied to individual pixels of the display. When the voltage is absent, the colored oil forms a continuous film within a pixel, and the color may thus be visible to a user of the display. On the other hand, when the voltage is applied to the pixel, the colored oil is displaced and the pixel becomes transparent. When multiple pixels of the display are independently activated, the display can present a color or grayscale image. The pixels may form the basis for a transmissive, reflective, or transmissive/reflective (transreflective) display. Further, the pixels may be responsive to high switching speeds (e.g., on the order of several milliseconds), while employing small pixel dimensions. Accordingly, the electrowetting displays herein may be suitable for applications such as displaying video content. In addition, the lower power consumption of electrowetting displays in comparison to conventional LCDs makes the technology suitable for displaying content on portable devices that rely on battery power.

The electronic device **400** also includes one or more processors **420** and computer-readable media **422**. Depending on the configuration of the electronic device **400**, the computer-readable media **422** may be an example of tangible non-transitory computer storage media and may include volatile and nonvolatile memory and/or removable and non-removable media implemented in any type of technology for storage of information such as computer-readable instructions or modules, data structures, program modules or other data. Such computer-readable media may include, but is not limited to, RAM, ROM, EEPROM, flash memory or other computer-readable media technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, solid state storage, magnetic disk storage, RAID storage systems, storage arrays, network attached storage, storage area networks, cloud storage, or any other medium that can be used to store information and which can be accessed by the processors **420**.

The computer-readable media **422** may be used to store any number of functional components that are executable on the processors **420**, as well content items **424** and applications **426**. Thus, the computer-readable media **422** may include an operating system and a storage database to store one or more content items, such as eBooks, audio books, songs, videos, still images, and the like. The computer-readable media **422** of the electronic device **400** may also store one or more content presentation applications to render content on the device **400**. The content presentation applications may be implemented as various applications **426** depending upon the content items **424**. For instance, one of the applications **426** may be an electronic book reader application for rending textual electronic books, an audio player for playing audio books or songs, a video player for playing video, and so forth.

The electronic device **400** may also includes one or more power sources **428** for providing power to the display stack **402** and one or more communication interfaces **430** to facilitate communication between one or more networks (such as the Internet® or one or more local area networks) and/or directly with one or more devices. The communication interfaces **430** may also facilitate communication between one or more wireless access points, a master device, and/or one or more other computing devices as part of an ad-hoc or home network system. The communication interfaces **430** may support both wired and wireless connection to various networks, such as cellular networks, radio, WiFi networks, short-range or near-field networks (e.g., Bluetooth®), infrared signals, local area networks, wide area networks, the Internet, and so forth.

FIG. **5** is a flow diagram illustrating example processes for generating a display stack as described herein. The processes are illustrated as a collection of blocks in a logical flow diagram, which represent a sequence of operations, some or all of which can be implemented in hardware, software or a combination thereof. In the context of software, the blocks represent computer-executable instructions stored on one or more computer-readable media that, which when executed by one or more processors, perform the recited operations. Generally, computer-executable instructions include routines, programs, objects, components, data structures and the like that perform particular functions or implement particular abstract data types.

The order in which the operations are described should not be construed as a limitation. Any number of the described blocks can be combined in any order and/or in parallel to implement the process, or alternative processes, and not all of the blocks need be executed. For discussion purposes, the processes herein are described with reference to the frameworks, architectures and environments described in the examples herein, although the processes may be implemented in a wide variety of other frameworks, architectures or environments.

FIG. **5** illustrates an example flow diagram showing an illustrative process **500** for forming the display stack of FIGS. **1-3**. For example, a display stack may include a cover component, a front light component, a display component, and/or one or more layers of OCA. At **502**, a lacquer is applied to a substrate to generate a lightguide. For example, the lacquer may be applied to a PMMA plastic substrate, together with multiple grating elements that function to propagate light from the light source towards the top surface of the display stack. In some examples, the grating elements

may be configured to stick out or extend outwards into the lacquer to form a positive relief. The lightguide may then be UV-cured or hardened.

At **504**, the lightguide is contacted with a first layer of silicone OCA. The silicone OCA may be a film or a liquid. The first layer of silicone OCA may have a predetermined refractive index based at least in part on an amount and thickness of the OCA layer. For example, the silicone OCA may be may be substantially 150 um thick.

At **506**, a second layer of silicone OCA is contacted with a display component. The second layer of silicone OCA may be cured or hardened to bond the display components into the display stack. For example, the OCA may be UV-cured on the corners and/or around the perimeter, as discussed above, or the silicone LOCA may be placed near a center and pressed outwards towards a perimeter of the display stack while UV-curing.

At **508**, an antiglare material is applied to a top surface of a coverglass. For example, the top surface may be coated with a material having antiglare proprieties in addition to antireflective properties, anti-smudging or anti-fingerprinting properties, anti-cracking properties, among others that may be cooled or UV-cured. In other examples, an antiglare film may be adhered to the top surface of the coverglass. In some other examples, the antiglare layer may be formed be etched into the top surface of the coverglass using for example a chemical spray.

At **510**, a touch layer is applied to the bottom surface of the coverglass. For example, the touch layer or touch pattern may be formed by depositing traces of ITO onto the bottom surface of the coverglass, printing a conductive ink onto the bottom surface of the coverglass, or adhering a pre-formed metal mesh or wiring to the bottom surface of the coverglass. In some specific examples, the touch layer may be formed by applying ITO to the coverglass using physical vapor deposition, electron beam evaporation, or sputter deposition techniques among others.

At **512**, an acrylic OCA is contacted with the first layer of silicone OCA. For example, the acrylic OCA layer may have a predetermined UV or luminous transmittance rating and the silicone OCA may have a predetermined refractive index. In some implementations, both the acrylic OCA and the silicone OCA may be a SOCA or film. The SOCA may be die-cut to fit the dimensions associated with the display stack and the resulting OCA layer may be laminated using an auto glaze process to reduce bubbles that may form manufacturing defects.

At **514**, the coverglass is contacted with the acrylic OCA. The acrylic OCA may be cured or hardened to bond the coverglass with the lightguide. For example, the OCA may be UV-cured on the corners and/or around the perimeter, as discussed above, or the silicone LOCA may be placed near a center and pressed outwards towards a perimeter of the display stack while UV-curing.

In another particular example, the acrylic OCA may be a film 100 micrometers (um) thick and the silicone OCA may be a LOCA 50 um thick. In the present example, the acrylic OCA film and the silicone LOCA may be applied in a vacuum under a pressure of 50 Pa or less for 20 to 30 seconds. By substituting a silicone LOCA for the OCA film, some manufacturing steps may be removed, such as the auto glaze process, as the number of bubbles that typically form between the OCA films may be reduced and/or eliminated when a LOCA is utilized. Thus, a display stack manufactured utilizing a silicone LOCA may be produced having better yields, reduced mechanical failures, and at a cheaper cost. For instance, when two OCA films are laminated particle bubbles (e.g., air gaps around particles or dust between the films) may form. These bubbles may result in device failure when the electronic device is exposed to heat, pressure, or a combination thereof, such as during stress testing. Thus, by substituting a LOCA for one of the OCA films, the number of defects and steps associated with the manufacturing process of the display stack may be reduced, resulting in a cheaper higher quality display.

At **516**, the edges of the coverglass are inked using an oil based marker. The oil based mark is applied such that light being scattered as the light travels through the coverglass may be captured or contained by the oil based marker or ink to prevent the coverglass from acting as a lightguide.

At **518**, the lightguide is contacted with the second layer of silicone OCA to bond the lightguide to the display component. Again, the OCA layer may be UV-cured or hardened to bond the display component and lightguide together. For example, the OCA may be UV-cured on the corners and/or around the perimeter. Thereafter, the remaining OCA may be UV-cured. By curing the corner(s) and/or perimeter, the techniques effectively create a barrier for the remaining OCA and also prevent the formation of air gaps in the OCA layer, thereby increasing the display stack. In other implementations, the silicone LOCA may be placed near a center and pressed outwards towards a perimeter of the display stack while UV-curing.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as exemplary forms of implementing the claims.

What is claimed is:

1. An electronic device comprising;

a display stack including:

- a coverglass with a top surface and a bottom surface, the top surface of the coverglass being etched to impart antiglare proprieties;
- a touch layer contacted with the bottom surface of the coverglass;
- a lightguide positioned beneath the coverglass and configured to receive light from a light source located adjacent to the lightguide;
- a first optically clear adhesive (OCA) layer to bond the bottom surface of the coverglass to a top surface of the lightguide, the first OCA layer including an acrylic OCA with a predetermined luminous transmittance rating and a silicone OCA with a predefined refractive index;
- a display component positioned beneath the first OCA layer, the display component configured to display content;
- a second OCA layer to bond the lightguide to the display component; and
- a ring adhesive disposed around an outer edge of the display stack, the ring adhesive extending from the top surface of the coverglass downward to a bottom surface of the lightguide.

2. The electronic device as recited in claim **1**, wherein the ring adhesive covers at least a portion of the vertical side surfaces of the display stack and includes at least at least one flexible portion formed from a foam material and at least one rigid portion formed from an optically clear adhesive to allow the display stack to flex.

3. The electronic device as recited in claim **1**, wherein the acrylic OCA has a luminous transmittance rating of greater

than 90% above 400 nm wave length and less than 5% below 350 nm wavelength and the silicone OCA has a refractive index of 1.41.

4. The electronic device as recited in claim **1**, further comprising:

an ambient light sensor, the ambient light sensor outputs a signal based at least in part on an amount of ambient light detected and wherein the signal is used by the device to control an amount of illumination generated by the light source; and

an opening to allow light to reach the ambient light sensor.

5. A display stack of an electronic device, the display stack comprising:

a cover component;

a first optically clear adhesive (OCA) layer contacted to a bottom surface of the cover component;

a second OCA layer contacted to the first OCA layer;

a front light component positioned beneath the second OCA layer;

a third OCA layer contacted to a bottom surface of the front light component;

a display component positioned beneath the third OCA layer; and

a ring adhesive disposed around the outer edges of the display stack.

6. The display stack as recited in claim **5**, wherein the first OCA layer is formed from an acrylic OCA having a predefined luminous transmittance rating and the second OCA layer is formed form a silicone OCA having a predefined refractive index.

7. The display stack as recited in claim **5**, wherein the first OCA layer is formed from an OCA having a luminous transmittance rating of greater than 80% above 400 nm wave length and less than 5% below 350 nm wavelength and the second OCA layer is formed form a silicone OCA having a refractive index of 1.39 to 1.51.

8. The display stack as recited in claim **5**, wherein the first OCA layer is formed from an OCA having a luminous transmittance rating of greater than 90% above 400 nm wave length and less than 1% below 350 nm wavelength and the second OCA layer is formed form a silicone OCA having a refractive index of 1.41.

9. The display stack as recited in claim **5**, wherein the front light component includes:

a light source; and

a lightguide to propagate light generated by the light source.

10. The display stack as recited in claim **5**, wherein the cover component includes:

a coverglass having a predefined antiglare propriety; and

at least one touch layer contacted with a bottom surface of the coverglass.

11. The display stack as recited in claim **10**, wherein the cover component includes an oil based ink disposed around an edge of the coverglass.

12. The display stack as recited in claim **10**, wherein the cover component further comprises:

a first black mask extending form an edge of the display stack to a first location beneath the coverglass; and

a second black mask extending from the edge of the display stack to a second location beneath the coverglass, the second black mask arranged below the first black mask, and the second location being closer to the edge of the display than the first location.

13. The display stack as recited in claim **5**, wherein the ring adhesive extends downward to a bottom surface of the front light component and covers the vertical side surfaces of the display stack.

14. The display stack as recited in claim **5**, wherein the ring adhesive includes at least one flexible portion formed from a foam material and at least one rigid portion formed from a plastic material.

15. The display stack as recited in claim **5**, wherein the display component includes a front plane laminate positioned atop a substrate.

16. A method comprising:

providing a display component having a top surface;

forming a first optically clear adhesive layer over the top surface of the display component;

providing a lightguide having a top surface and an opposing bottom surface;

forming a second optically clear adhesive layer over the top surface of the lightguide;

forming a third optically clear adhesive layer over the second optically clear adhesive layer;

contacting a cover component to the third optically clear adhesive, the display component, lightguide, and cover component forming a display stack; and

applying a ring adhesive around an outer edge of the display stack.

17. The method as recited in claim **16**, further comprising etching a top surface of the cover component to impart antiglare properties to the top surface of the cover component.

18. The method as recited in claim **16**, wherein the second optically clear adhesive layer is liquid and includes a silicone material and the third optically clear adhesive layer includes an acrylic material.

19. The method as recited in claim **16**, wherein forming the third optically clear adhesive layer includes vacuum laminating the second optically clear adhesive layer and the third optically clear adhesive layer at a pressure of under 50 Pascals and for a time period of between 20 and 30 seconds.

20. The method as recited in claim **16**, further comprising forming a touch sensitive layer on a bottom surface of the cover component.

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